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SIMULATION CITY APPROACH FOR PREPARATION OF URBAN AREA DATA BASES

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The concept is first described in general terms, and then supported by a review of theoretical and empirical studies which would be valuable in its realization. The trade-off between cost and accuracy in modeling is then more explicitly considered.

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SIMULATION CITY APPROACH FOR PREPARATION OF URBAN AREA DATA BASES

by

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Contract No. 68-01-1805
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ABSTRACT

This report presents a preliminary exploration of feasibility of a Simulation City Approach to the preparation of urban area data bases for environmental policy analyses. The Simulation City Approach is presented as a means of making complex comprehsnsive environmental planning models more accessible for a broad range of policy level questions by effectively reducing the difficulty and cost of applying these models.

The basic hypotheses of the Simulation City Approach is that it is possible to approximate the detailed input data base required for complex planning models, given only a relatively gross description of a specific metropolitan area and general knowledge of patterns of urban composition. This approximation is accomplished at a substantial reduction in the costs associated with data preparation and thus planning models, at relatively little expense in terms of accuracy. Accuracy is here judged in terms of the final decision to be made on the basis of planning model analyses. To the extent that the hypothesis is valid in a particular application, a decision-maker is given the opportunity to ask a range of questions at substantially reduced cost and time expense.

The concept is first described in general terms, and then supported by a review of theoretical and empirical studies which would be valuable in its realization. The trade-off between cost and accuracy in modeling is then more explicitly considered.

The investigation of the Simulation City Concept was undertaken within a context of application to the General Environmental Model (GEM), a comprehensive environmental planning tool being developed by EPA. It is concluded that the approach is a promising one for policy-level analysis, and offers a means of bringing the cost and difficulty of application of large planning models into line with the problems they are best suited to address.

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Dr. Philip Paterson and Mr. Albert Pines of the EPA Office of Research and Monitoring administered this project. Their assistance is acknowledged with sincere thanks.

This report presents the results of a study into an innovative approach to the preparation of input data for large scale planning models. This approach is not without precedent; drawing upon prior work by the consultants, utilizing a range of published research in urban systems structures [1], and taking a measure of encouragement from work in other fields [2], the Simulation City concept has a broad range of potential applications.

However, this study has been conducted with the intention of a direct application to the General Environmental Model, under development by the Research and Monitoring Division of EPA. No attempt has been made to explain fully the details of GEM, and some knowledge of the model's characteristics is assumed. The body of the report minimizes the level of this assumed knowledge, however, and the bulk of the argument related specifically to GEM is presented in appendices.

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1. See the Voorhees reports in the bibliography.
2. See, for example, Rand Corporation work.

SECTION I
CONCLUSIONS

The purpose of this report has been to describe the Simulation City approach to data preparation, to present arguments regarding the possible feasibility of implementing the concept, and to describe in a preliminary fashion (see appendices) the design of a Simulation City model intended to provide input data for GEM. As has been explained, the Simulation City concept is potentially applicable to a range of large-scale planning models, although a principal motivation for the current study has been to explore the concept for the particular case of application to GEM. Thus, it is appropriate to state separately certain conclusions which are directed to the GEM system. Further, recommendations will be made as to what might be done to proceed with the work, to implement a GEM-linked Simulation City model.

SOME GENERAL CONCLUSIONS

The Simulation City concept is proposed as a means of developing a data base for a large scale planning model, at a significantly reduced cost and relatively small loss in accuracy. Chapter II reviewed the background information which supports the technical feasibility of the concept, and Chapter III addressed more directly the considerations of cost and accuracy. Based upon these discussions, the following conclusions are suggested:

1. The Simulation City concept is a feasible and potentially valuable approach to data preparation for large scale planning models.

2. A Simulation City model, linked with an appropriate planning model, will be most useful in the analysis of planning questions at the policy level. This conclusion is based primarily on considerations of the overall loss of predictive accuracy anticipated to result from dependence on data simulation.

3. A Simulation City model will not only be most useful at the policy level, but will actually render the planning model more accessible to the decision-making process. Frequently there are questions asked at the policy level for which there is too little time or too uncertain an understanding of the magnitude of the problem to justify expenditure of the resources required to complete a standard data collection and analysis effort. The Simulation City model would make it practical to ask a fuller range of questions.

CONCLUSIONS FOR GEM

Beyond the general conclusions stated above, there are statements which may be made about the Simulation City concept as applied to GEM:

1. Because of the extremely comprehensive nature of GEM, development of a Simulation City model for this application will represent a test of the extent to which the concept may be applied.
2. However, the unique features of GEM input requirements makes the evaluation of a Simulation City model more difficult in any terms other than with respect to final planning decisions. The question of accuracy will require careful consideration.
3. The potential savings in data expenses and the consequently increased availability of the GEM system for policy exploration makes the implementation of a GEM-linked Simulation City model an apparently worthwhile undertaking.

SOME IMPLICATIONS

The conclusions stated above may be used as a basis for considering the value of the simulation concept and thereby for identifying implications for its use:

1. Because the model would be based on a consistent set of rules, application of a Simulation City Approach across a variety of metropolitan areas would result in a consistent set of data bases. These data bases would be consistent in the sense that they would have similar levels of detail, source of error, and statement of characteristics. Such data bases would be of value in undertaking consistent studies of EPA policy across a variety of urban areas.

2. Linked with appropriate environmental analysis model, a Simulation City Model could be used to develop sketch planning tools for local area planners. Such tools would be used in preliminary planning analysis, to identify major types of plan alternatives which would be feasible and beneficial on environmental grounds. A simple sketch planning tool would make the concepts and practice of environmental planning more accessible to small communities and the general public.

SECTION II
RECOMMENDATIONS

Based upon the investigation and conclusions of this study, it is recommended that an effort be made to implement a Simulation City model for GEM. It is further recommended that the implementation be undertaken in several steps:

- A detailed design and coding of the simulation should first be completed. These efforts should be coordinated closely with ongoing developments in the GEM system.
- The Simulation City model should then be given preliminary testing, through generation of several data bases. These data bases would be compared with bases created "by hand."
- A test of the entire GEM system should be made, using the Simulation City model, to investigate the impact of the model on GEM's role in decision-making.

This last step is especially important, for it is upon its potential value to policy explorations that the justification for the Simulation City concept rests.

A Simulation City model should be most accurate in those areas where its related planning model is most sensitive. The simulation may be quite acceptable with relatively large errors in other areas. No conclusive judgment can then be made by looking at raw data alone.

In summary, this exploration of the Simulation City approach should continue. But it should continue in a context of its ultimate use, with concern for its role in a planning and decision-making process.

SECTION III

THE SIMULATION CITY CONCEPT

In addressing the myriad problems of planning and decision-making for the environment, the development and application of computer based models has emerged as a major area of activity. While there may be considerable question regarding the validity of individual efforts (See, for example, the growing literature surrounding Forrester's work [1,2]), there can be no question that modeling ferver is widespread and represents potentially a very promising approach to problem solving.

Modeling for environmental analysis has extensive antecedent--in philosophy, content, and common personnel--in urban and transportation planning. Models for land use and travel prediction and analysis have been the subject of substantial study and debate (Lee's discussion [3] is instructive) for many years, and are now providing the basis for many environmental modeling efforts.

One outstanding feature which runs throughout all of these efforts is the level of resources typically devoted to the collection of data and preparation of this data for use in analysis. It has been the experience of this consultant, for example, that a minimum of 20 percent of the cost of applying land use models will be directly associated with data collection, while in the case of standard travel analyses, 45 percent to 50 percent of the cost is likely to be incurred before any real analytical efforts can be made. The nature of these data requirements severely limits the range of situations to which models may be applied. Only when a major study is undertaken, or when there is clearly an ongoing need for analytical capability will the level of resources available be adequate to support an application of models, requiring large input data bases.

In contrast to the situation in which application of models may be financially feasible is the typical situation in which models might be most useful: public decision-makers often have questions about the possible results of one or another course of action, questions which arise in the ongoing formulation and application of policy. An immediate solution is desired, and it therefore is assumed that accuracy or certainty in prediction may be sacrificed in order to achieve a quick decision. Models, as currently designed, provide little assistance in this incremental decision making context.

Even in the slower, more detailed analyses in which models are most often employed, the planner is seeking a level of accuracy and detail well beyond that which the model, as an abstraction of a partially understood physical and socio-economic system, can provide. Clearly, there is a need to shift the focus of such analyses.[3, 4]

There is a need to perceive more clearly the capabilities and limitations of models and to balance the allocation of effort in utilizing models. It is in response to the need for balance that the Simulation City Approach is proposed. By simplifying and substantially reducing the effort required to prepare a data base for environmental analysis models, these models will be rendered considerably more accessible and useful to the planning and decision-making process.

WHAT IS THE CONCEPT OF SIMULATION CITY?

The underlying hypothesis of the Simulation City Approach to environmental data preparation is that the level of accuracy at which environmental models operate does not justify the detail required in their input and, further, that quite acceptable and useful results may be obtained by using less accurate input. That is, it should be possible to utilize more approximate input data,

with an associated reduction in acquisition and preparation costs, with relatively little overall deterioration in the value of the modeling exercise.

The approach is based upon a concept that there is a sufficient body of knowledge about the structure and operating character of the system of activities comprising a metropolitan area to permit the simulation of a considerable portion of the detailed description of an area. Based upon a knowledge of the principal industry and median income in an area, for example, one may infer a great deal about the socio-economic character of the area. To do so, one needs some knowledge of the current character of the country as a whole, and of the body of research available in urban economics. Similarly, a knowledge of total population will allow one to make a reasonable assumption about the amount of land area occupied by urban development.

Simulation of a city, in terms of a detailed descriptions of that city's characteristics, cannot replicate the actual, "real world" situation. However, a successful simulation will possess a sufficient similtude to the real world that the environmental model which utilizes the data will induce the same decisions as would be made with "perfect" knowledge of the environment. To make an analogy, the dimensions of a building plan are not specified in fractions of an inch. Decisions regarding the allocation of space may be made on a coarser basis.

A Simulation City Model would thus be a means of approximating the fine description of a metropolitan area, as required for input to one or more planning models. To be useful, such a model must be able to produce input having sufficient resemblance to the real city that the final analytical results indicate the same conclusions as would have been reached with standard methods. It is then apparent that any realization of a Simulation

City Model will be influenced significantly by the analytical model or family of models to which it will be providing input. Accuracy in simulation is more important for those items of data to which the analytical planning model is most sensitive, and the form of simulation output must be accepted by the planning model.

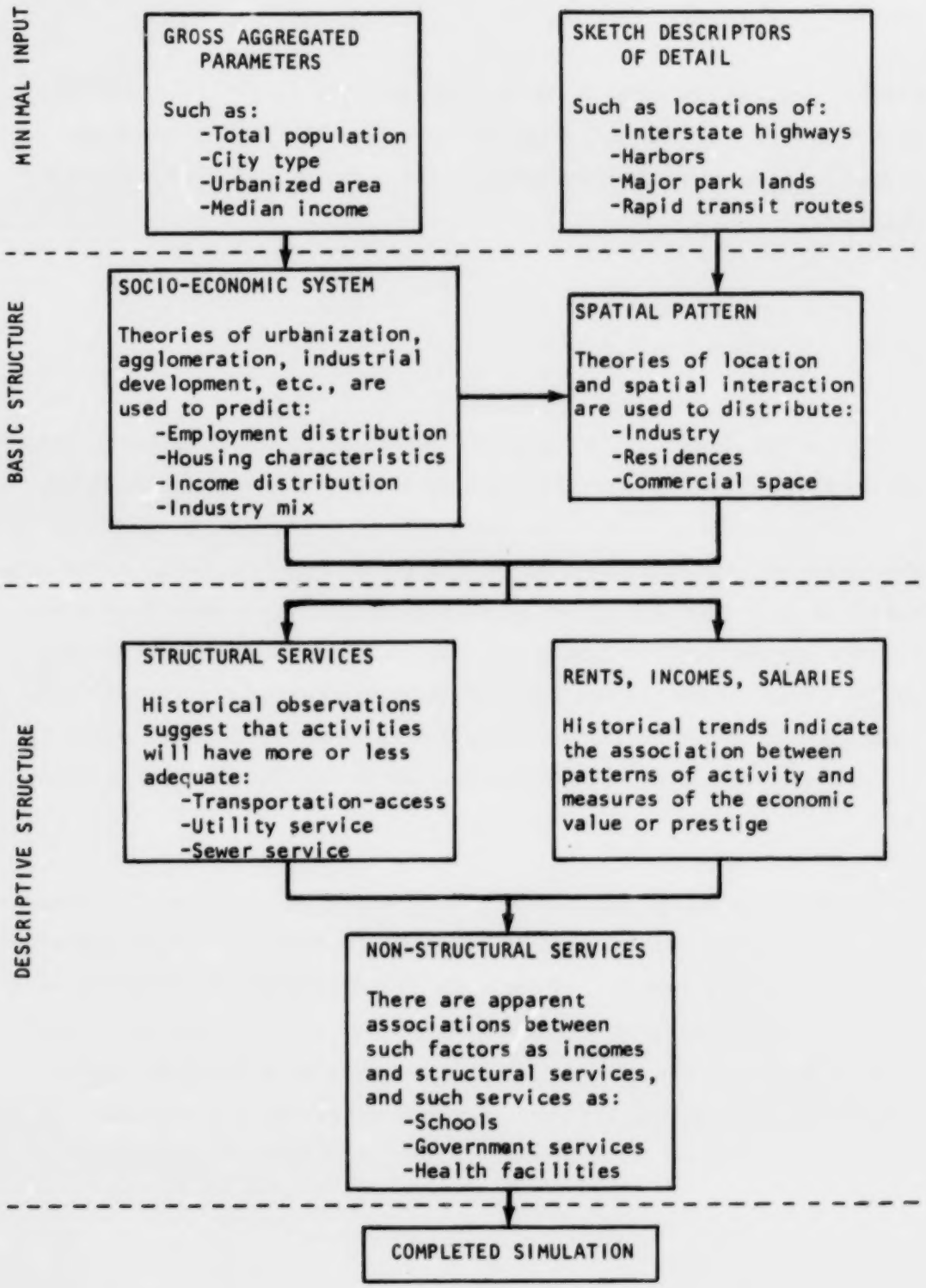
These requirements complicate the development of a Simulation City model: It is necessary to accommodate the input requirements of the planning model while producing an acceptable representation of reality. On the other hand, the planning model may limit the scope of the simulation via its limited abilities to accept a variety of input.

COMPONENTS OF A SIMULATION

Figure 1 indicates, in a very general manner, how a Simulation City model might be constituted. As shown, there would be two types of information required for simulation: aggregate parameters which are representative of the overall socio-economic system of the city, and descriptors of detail, which give a sketchy picture of the city's spatial distribution of activity. The simulation is intended to infer a good deal more detail about the socio-economic system, given some knowledge of what cities in general have in common, and to postulate how the socio-economic activity is distributed over the skeleton of pattern provided by the sketch descriptions. A picture of the level and distribution of activities which comprise the basic structure of the city is thus developed.

Observations of how cities in general operate and grow permit some aspects of the city's character to be inferred from this description of basic structure. For example, population density and median income are found to be negatively correlated in residential areas.[5/] Provision of adequate road access must generally precede development of an area,

FIGURE 1 MAJOR COMPONENTS IN A SIMULATION CITY



so that a prediction that an area has been developed implies an assumption that such access exists.

Finally, schools and other municipal services will be provided, but their quality is quite variable and dependent upon the individual community. Simulation thus requires some judgment or measure of the community's character.

UNDERTAKING A SIMULATION

As a general rule it may be suggested that the ability to simulate accurately the characteristics shown in Figure 1 decreases as one moves down the path from minimal input to final output. Predictive ability is increased by the requirement of more extensive input, up to the point that an entire data base is simply developed by hand. But the further one proceeds with the simulation, and the more one minimizes the required input, the greater is the saving in time, labor, and monetary expense in preparing the data base. It is this trade off between accuracy and cost which represents the central point in judging whether the Simulation City Approach is a viable one.

In the following pages, the tradeoff will be explored. Chapter II presents a summary of some of the theoretical and observational considerations which suggest that, as a general concept, the Simulation City Approach is valid. Chapter III addresses directly the question of accuracy, and the tradeoff between accuracy and cost, in general and relative to the GEM system. Chapter IV summarizes the considerations presented in preceding chapters and suggest conclusions regarding the value of proceeding with

development of the Simulation City Approach to data preparation. Appendices present the exploration of a GEM-linked Simulation City Model which provided background for much of the argument in the text.

SECTION IV
BASES FOR SIMULATING A CITY

In considering the body of theory and observation which is available as a basis for development of the Simulation City approach, it is important to recognize that the Simulation City model is not intended to be predictive, in the sense of most planning models. There is no consideration given to future conditions, and hence no debate regarding whether the model is in any sense normative. A Simulation City model is intended to be purely descriptive -- descriptive of the present conditions in a given city. It is then not unrealistic to expect that wherever theory is inadequate to explain the patterns of urban development, statistics may fill the void.

With these points in mind, a search may be made to find what theories and facts are available, and whether what is available is adequate to make development of the Simulation City approach a practical undertaking. In this chapter, the findings of such a search are reviewed.

TYPES OF URBAN AREAS

Attempts to classify urban areas -- cities -- into typical categories has been a relatively popular area of research among geographers and planners. Work by Harris[6/] was among the earliest to attract attention, while that of Berry[7/] reflects the recent trend toward applications of advanced statistical methods. While it has been felt by many observers[8/] that there has been inadequate thought given in the conduct of such research to why one should classify cities and what is thereby accomplished, such work represents a resource for the simulation city approach: it is

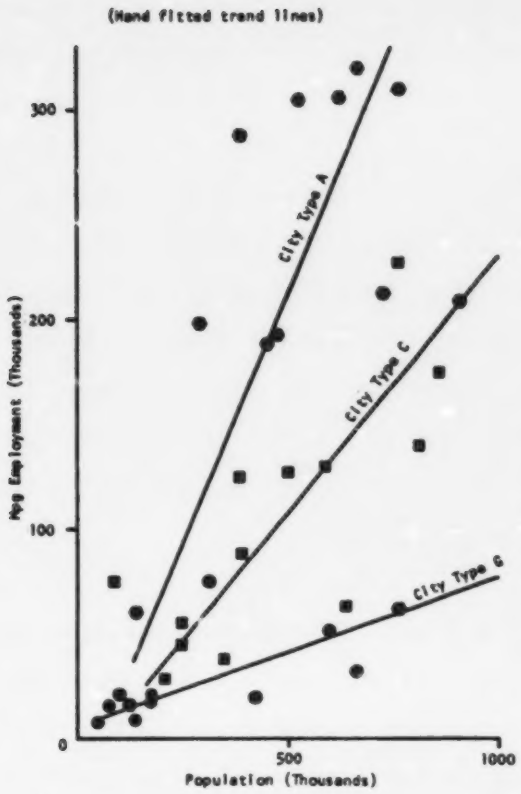
apparent that the statistics which identify groups and distinguish them from one another are better predictors of the characteristics of an individual city with the group than are the statistics for all groups combined.

Recent work by Pidot and Sommer, [9] for example (Golub, et. al.[10] had similar findings), tested variables of population, education, social character, housing quality, labor base, and industrial character for standard metropolitan statistical areas in the U.S. (excluding such unique cases as New York), and found what they considered to be an optimal grouping into nine categories. One group was characterized, for instance, as heavily oriented to recreational activity, while another had high components of elderly population.

These categories suggest a way to predict more accurately certain characteristics of a metropolitan area. As Figure 2 illustrates, for example, there is a quite noticeable difference in the fraction of work force in manufacturing employment among different classes of cities. In contrast, Figure 3 indicates that the effect of city type is much less pronounced in the case of retail employment.

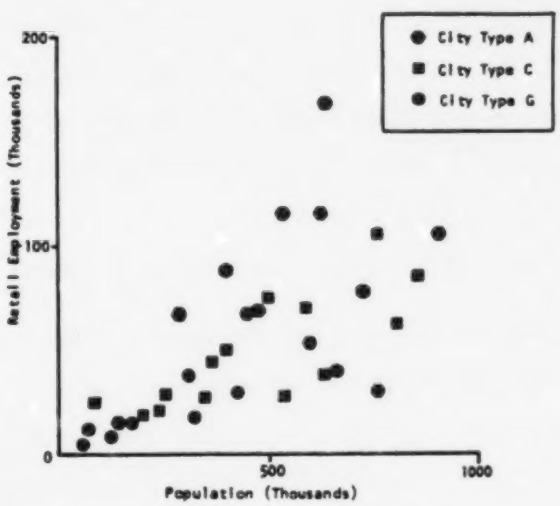
Classifications of city type, such as those mentioned here, are typically most dependent upon population and industry characteristics for these comprise the basis of the city's existence. It is hardly surprising then that there should be empirical relations such as those shown in Figures 2 and 3. But there is reason to suppose that there are other categories which could be applied at a lower level of detail to give other types of useful relationships.

For example, there has been substantial literature produced in study of the theory and process of agglomeration among businesses. According to the theory, first postulated by Weber,[11] industries tend to cluster, spatially, to take advantage of economies of scale in minimizing transportation costs for intermediate goods. Explorations of the theory have led to the concept of industrial clusters, groups of industries which are



Source: Statistical Abstract of the United States, City Types, Pidot and Sommer 9/

FIGURE 2 MANUFACTURING EMPLOYMENT AS RELATED TO POPULATION AND CITY TYPE



Source: Statistical Abstract of the United States, City Types, Pidot and Sommer 9/

FIGURE 3 RETAIL EMPLOYMENT AS RELATED TO POPULATION AND CITY TYPE

found in many urban areas. Bergsman, et. al.,[12] found four widespread clusters in their preliminary analysis, which they termed market center, low wage apparel, labor intensive, and southern textile. Such work suggests that indication of the major industry or cluster type in an area might prove sufficient to simulate the industrial composition of the area, in terms of economic importance (such as sales, value added labor proportion, or other measures). Morrisett's[13] findings on minimum employment levels as a function of city size supports this concept.

On the other hand, a number of unique economic systems were noted in this work. New York, Los Angeles, and Chicago are not surprising in this category, but cities such as Philadelphia and Akron are perhaps less expected as singularities. Looking at incomes in relation to industry mix and employment, Bryce[14] suggested that roughly 30 percent of metropolitan areas have demographic profiles which could best be termed atypical. Such findings indicate that it may not be reasonable to carry the stratification of cities into type categories on too detailed a level.

Somewhat related to the concept of distinct types, based on industry and demography, is that of the economic base. Drawing from international trade theory, regional economists postulate (see Blumenfeld's discussion, for instance[15]) that industries which export the bulk of their production from the region, thus drawing cash into the region, comprise the base of the region's economy. The employees associated with these businesses have a need for services -- retail outlets, building trades, etc. -- which stimulates the flow of goods and services in an urban economy.

There are generally 15 percent to 30 percent of all workers employed in these service industries*, with the percentage rising as city size grows. This latter observation stems from the larger city's importance as a center of a larger region of activity. It would seem then that one might predict the number of workers in a city of given population, and the likely split of these workers between basic and service businesses, without reference to more detailed categories.

INFRASTRUCTURE OF THE URBAN ECONOMY

While attempts at stratification of urban areas focus upon differences among types, there has been considerable theoretical and historical support for the idea that there are certain consistencies of structure underlying the economies of all cities. Location theory suggests that the initial formulation of a settlement in an area (see Isard's introductory discussion[16]), is highly dependent upon its physical site. The site therefore may reveal a good bit about the city. For example, location on a river suggests a transport orientation, and shipping in or out of heavy raw materials. Location at a source of natural resources indicates information about the probable mix of labor.

More interesting, from the standpoint of a simulation city model, are observations about supplies of services in urban areas. Another aspect of the agglomeration process mentioned above is that urbanization supports economies of scale, relative to provision of such infrastructure services as sewer, water, electricity, and schools. Borcherding,[17] for example, was able to develop regression equations to predict with fair accuracy the dollar expenditures on such services. Other investigations (see Stone[18] and Sussna,[19] for example) have reported sufficient consistency among urban areas to lend support to the idea that there may be an optimum city size, relative to minimization of per capita service costs.

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* Some definitions of service employment include as much as 50 percent of the total employment

Similar consistencies are found in the provision of transportation services. Highway lane-miles[20] or percentage of land in highway use are approximated by a function of population and urbanized land area. Although public transit service is not so well defined, which may be due largely to the lack of consistent data, Wells[21] was able to develop predictive regression equations for route-miles of supply.

SIMULATION OF THE SOCIO-ECONOMIC SYSTEM

The above discussion has been concerned with general characteristics of urban demography and economy. Referring back to Figure 1, such information may provide the basis for simulating the basic structure of the socio-economic system of an urban area. At the extreme, simulation might proceed on the basis of only an estimate of total population and a city type designator or basic/service ratio.

From these two bits of data, the size of the workforce might be estimated, and a split of this workforce into industry categories made. The split might be simply basic versus service, or might deal with major activities such as manufacturing, retail, and wholesale. Some inferences about the distribution of income might be drawn.

Given a value for the median income, an income distribution is derived and utilized to infer a distribution of land values and rental costs for the area. Total supply levels of services and transportation facilities are then estimated.

In this fashion, a general, aggregated picture of the city is developed. Simulation of these aspects of the city might be considered analogous to the reconstruction of a set of accounts for a company in which the records have been lost. This part of the simulation has not directly addressed the

spatial distribution of activities within a region, which will be discussed in the following sections.

HISTORICAL PATTERNS AND LOCATION THEORY

The analysis of why certain activities are located in certain places, and of how individual locations combine into the pattern of a metropolitan region, has focused upon a trade-off between attractive features of a piece of land and the problems of gaining physical access to that land. In these terms, the location of a city at the site of a good harbor, rail terminus, or concentration of mineral wealth is analogous to the location of higher income residences within the metropolitan areas on sites with high ground, good vegetation, and highway service.

Emphasis on attractions of particular areas within a region is reflected in work such as that of Hoyt,[22] who was among the earlier analysts to devise a coherent explanation of the patterns of activity within an area. His sector theory, which addresses residential location and urban growth, postulated that similar activities would tend to grow outward from the center city in wedge-shaped land sections. The initial location of a sector was determined by factors attractive to the activity -- for example, higher ground for residential development: Hoyt pointed out that higher income residences tended to cluster along ridges.

More recent work, such as Timms,[23] has extended Hoyt's work into social analysis. Here, social rank as a whole, rather than simply income, is said to be distributed along sectoral lines, while status within a social class generally increases toward the center -- until a reversal occurs as one enters the central core area.

The extent to which the sector concept represents a contribution to urban theory rather than a restatement of historical development, is uncertain.

The radial patterns of highways and the street railways in the past several decades certainly have encouraged such segregation of activities, and have given characteristic forms to many cities.[24] The fact that the sector concept was useful in guiding decision making in real estate investment was adequate to justify its widespread acceptance.

An alternative focus is provided by the attempts to explore variations in the level of activity within an urban area. Density of development is the measure generally used, stated as people or jobs per unit area. Viewing the urban region as a whole, reasonably good success has been achieved with statistical fitting of an exponential function to patterns of density. Mills[25] presents one of the more recent and extensive efforts in this area, using a model of the form

$$D(x) = D_o e^{-\gamma u}$$

where $D(x)$ is the density of activity at a distance x from the center of the city, D_o is a central density measure, and γ is a gradient measure. As Figure 4 shows, there seems to be some consistency of the estimates of the parameters of this model within the city type categories discussed previously. Some geographers have attempted to use this type of approach to define the limits of urbanized areas (see Grytzell,[26] for example), to replace the artificial legal boundary as a limit of analysis. However, the model seems most useful in replicating activity in the most stable sections of the urban region rather than in the often decaying central core or newly growing fringes. On a regional level, the fitted function has been shown to provide a reasonable measure of the degree to which a city is centralized or dispersed.

On a micro-scale attempts have been made to explain density on the basis of particular factors of a site or subarea in a region. Chapin,[27] for example, listed five factors which influenced density of development:

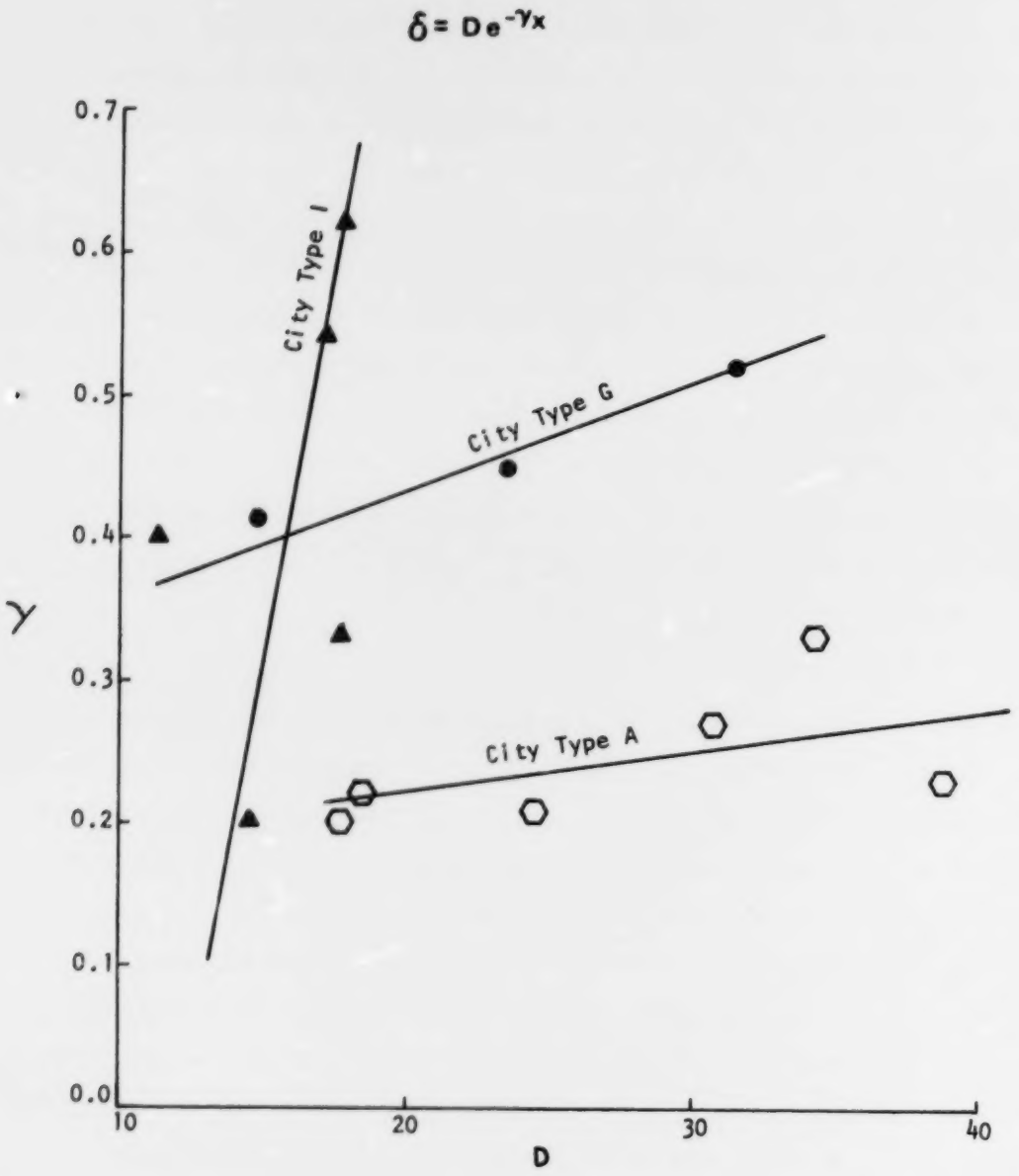

FIGURE 4 PARAMETERS OF THE EXPONENTIAL DISTRIBUTION OF ACTIVITY DENSITY IN CITIES

Source: Mills [25], City Types from Pidot and Sommer [9]

1. Poor drainage discourages development
2. Major transportation encourages development
3. Large employment potential intensifies development
4. Availability of services intensifies development
5. Proximity of blight and non-white areas discourages development.

Knowledge about the pattern of location of any of these factors could be useful in predicting the overall urban pattern.

TRANSPORT ORIENTATION

Something of a contrast to the above empirical studies is provided by the analyses undertaken with a strong transport point of view. Typically there has been an appealing model or theoretical approach to be applied, to which data has then been fitted. Hansen's[28] work is an example of one of the early efforts to formalize the role of distances among activities within an urban region as a locational factor, drawing upon earlier work in transportation where trip patterns were being predicted on this basis. (See Harris[29] also.)

The Lowry model of land use is perhaps the foremost representative of this approach (see Goldner's discussion[30]), in which the level of activity in a subarea is dependent upon the travel distance from that site to all other activities in the region. Wilson[31] strengthened the case for this type of model by demonstrating that it provides a maximum likelihood estimator of the area's pattern of development, given limited information on personal travel characteristics and the attractive features of a site, and there is a quite extensive literature in this area. Linked with models to predict (1) attractive features of subareas-- such as those discussed above -- and (2) mean trip length characteristics (see Voorhees[5]), the Lowry type model provides a useful predictor of density of activity.

A significant problem in these transport-oriented models (one present also, to a lesser degree, in the other work reviewed) is that they start from a knowledge of the locations of the principal -- or basic -- industries in an urban area. The factors determining the historical location of industries and thus their current patterns of spatial distribution, within a metropolitan region, have received little attention, although it might be expected for example that industrial concentrations would occur close to harbors and rail heads. Relative to current knowledge in this area, location of basic industries might be judged a random process. This situation obviously presents a potential problem for the Simulation City concept, for it cannot be said with any certainty that it would be possible to develop empirical predictors of industrial location as a function primarily of natural features. Greater user input would then be required.

DISTRIBUTION OF SOCIO-ECONOMIC FACTORS

Beyond the simple description of what activities occur in which areas of a metropolitan region, and with what intensity, there are a range of factors describing socio-economic qualities of these activities which must also be distributed spatially throughout the region. Rents, income, taxes, auto ownership, racial character, and many other such factors are of interest in various planning models. Bellomo, et.al., [32] for example, found that median income within subareas of a city was highly correlated with residential density. Rent levels and auto ownership would then be expected to be correlated with density, via their relationship to income.

Land values have been found (see Wieand [33] and Downing [34] for example) to be inversely correlated with distance from the central business district. As might be expected, commercial land value is higher along streets having higher traffic levels. Darling [35] was able to identify a

similar increased value in vacant land and residential areas, attributable to parkland having significant bodies of water.

The likely level of commercial sales at shopping centers was found (Lakshmanan[36]) to be related to accessibility as well as size. The accessibility of the center was computed as a function of the income of population surrounding the center, weighted by the distance of the population of given income from the center.

SIMULATION OF THE SPATIAL PATTERN

Referring again to Figure 1, the above paragraphs have been concerned primarily with simulation of the spatial pattern of the city, and to a lesser degree, with what is termed descriptive structure. Starting only with a few major features of the urban area -- major highways, rivers, lake or ocean frontage, location of city center -- it would appear to be feasible to simulate the locations of basic structural features: land use types and levels of activity.

First, estimates are made of the overall pattern of activity intensity, based upon city size and type. In general, intensity decreases exponentially as distance from the center increases. More specific information on intensity levels could then be inferred from the location of major features. Activity intensity concentrates along highways, for example.

The greater the amount of information which is input to the simulation, the greater will be the possible level of detail or accuracy. For example, if it is possible to indicate, prior to simulation, which sub-areas within an urban region are heavily developed, and which of these

subareas are older, it will be more reasonable to attempt to simulate the locations of services of all types -- sewer, utility, school, hospital. These activities are typically located as a function of political factors and land availability, and less often through consideration of access to users of most desirable building sites. It is then rather difficult to estimate location through information other than historical observation. This difficulty is also a reflection of the problems inherent in any simulation effort, as the level of detail to be simulated increases.

OVERVIEW: BASES FOR SIMULATION

The preceding discussion has attempted, through a brief review of a selection of theoretical and empirical studies in urban economics and geography, to illustrate that the concept of simulating a city -- or rather a detailed description of the city -- is perhaps a reasonable undertaking. Information such as that reviewed here provides a basis for devising a Simulation City model.

As has been pointed out previously, the appeal of the Simulation City approach stems from the possible trade-off between cost and accuracy in preparing a data base. It has also been pointed out that accuracy is, in this case, judged by how effectively the simulated data base reproduces the results which would be obtained by using a very detailed, hand built data base for input to a given planning model. It is this strong -- and quite necessary -- tie between a Simulation City model and the planning model for which it will be used which makes it impossible to judge with certainty how accurate, in general, a Simulation City might be. The quantity of work reported in the literature suggests that the concept is at least feasible, although simulation should not be carried too far.

The next chapter will examine the trade-off between analysis cost and accuracy which is the principal motivation for this study. If cost can be reduced sufficiently to make planning tools more accessible to decision-makers, without reducing accuracy so much as to render the model results useless, then the Simulation City approach will be a successful experiment.

SECTION V

THE TRADE-OFF OF ACCURACY AND COST

As stated above, the principal motivation for exploring the Simulation City concept lies in the possibility that an adequate data base might be produced for a given planning model, at a significantly reduced expenditure of time and other resources. The data base is judged to be adequate if it produces results similar to those which would be produced by a data base prepared by standard methods -- similar in the sense that the planner-decision maker using the model would reach the same conclusion with either base.

A GENERAL VIEW OF THE TRADE-OFF

The judgement of adequacy of a data base must ultimately be predicated upon the final results of analysis. Figure 5 illustrates the general concept of the postulated trade-off at this final level. It is an anticipated increase in accuracy of prediction which motivates efforts to increase the detail of analysis, which in turn is obtained at an increase in cost. An increase in detail and cost may be associated with the analytical model or with the data it utilizes as input.

Increasing cost will yield some increased accuracy, at a diminishing rate, up to some range where the present limit of knowledge is approached. In this range, current understanding of the functional and empirical relationships involved in a process are inadequate to deliver any increased accuracy, except perhaps on a purely chance basis. Further efforts to increase the level of detail in analysis may actually

reduce overall accuracy by introducing more potential sources of error and uncertainty.[3/]

The question to be addressed in judging the value of a Simulation City approach is whether, given a particular analytical model for which the data is to be provided, is the rate of trade-off of accuracy versus cost low enough that the potential savings in the cost are not outweighed by the losses in accuracy. Figure 6 illustrates this trade-off.

The potential differences in cost between a standard and a Simulation City approach may be substantial. A typical large scale urban transportation study, utilizing a standard battery of models, may easily have a cost in the range of $200,000 to $400,000. A large percentage of this cost -- up to 45 percent is not out of the ordinary -- may be associated with basic data collection and preparation. Only 15-20 percent of the cost is typically associated with the investigation of decision alternatives[4/].

Experience with analyses using a typical land use projection model provides another example. Here it is found that approximately $15,000 to $20,000 may be required in data preparation. This expense may represent 30 to 50 percent of the total cost of the analysis.

Experience with analyses using a typical land use projection model has indicated that approximately $15,000 to $20,000 may be required in data preparation. This expense may represent 30 to 50 percent of the total cost of the analysis.

It is estimated that preparation of a data base for the GEM model requires approximately $20,000 to $30,000 per city. In this case, a significant portion of the preparation work is judgmental, which tends to reduce costs.

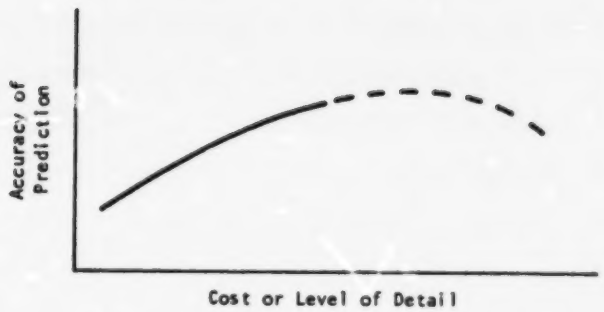

FIGURE 5 HYPOTHETICAL RELATIONSHIP OF COST AND ACCURACY IN PLANNING MODELS

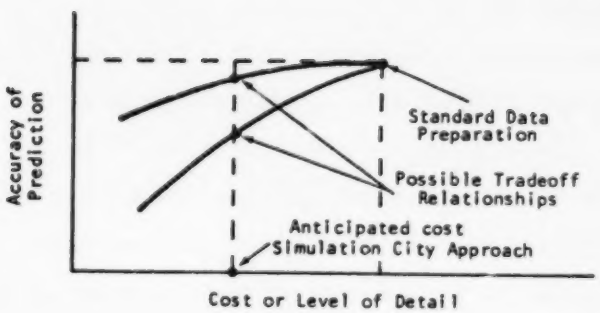

FIGURE 6 INFLUENCE OF UNCERTAIN KNOWLEDGE OF COST-ACCURACY TRADEOFF RELATIONSHIP

Clearly, there are great opportunities potentially available for the reduction of data-related costs. If, as preliminary estimates indicate, a Simulation City model could be implemented at a first cost of roughly $60,000, with a subsequent $5,000 or less required per data base, then the approach is quite promising. What makes the problem difficult is the lack of a straightforward approach to assessment of accuracy.

Errors or inaccuracies in models come from two sources: There are errors in measurement of data, which are carried through to the final results; and there are errors in the specification of model relationships, springing from lack of understanding or approximation of behavioral relationships.

That is, even if there were perfect knowledge and measurement of the conditions described by input data, there would be some degree of error in output.

A model will be of potential value in decision-making if the level of total error from these two sources is small relative to the critical ranges of decision variables. For example, an error of two to three million people in an estimate of the total population of the United States is of little consequence in discussion of national growth policies, while a similar absolute error would be clearly unacceptable for dealing with sewer investments within a single metropolitan area. The amount of error in a prediction must be viewed in proportion to the prediction itself and how it will be used. In the present context, two conclusions are implied: First, any judgment of a Simulation City approach must be made with a basic assumption that the combined errors inherent in the standard data preparation and utilization procedures are at an acceptable level. Second, because it is generally the case that less detailed information is required for policy decisions than for operating-design decisions, increased error introduced by a Simulation City approach will

tend to reduce the usefulness of the planning model for this latter type of decision, although not necessarily for the former.

A major problem with current planning models, and the studies which utilize them, is the lack of knowledge regarding levels and sources of error. In a typical transportation study, the various models are able to reproduce the base time period (observed) data on travel to within an overall range of error of approximately 10 to 20 percent. However, this level of accuracy is achieved through the manipulation of such a large number of factors that it is unclear what the sources of error might be. One useful study in this area[37/] suggests that the variation is due largely to data, and in fact may represent an over-correction of variance. Further, this level of variation might lead, at the extreme, to a shift in decisions about operational matters (such as numbers of highway lanes, and in contrast to policy matters) in fewer than one-third of all cases, a finding which casts light on the influence of error.

It might then be concluded that the base-line level of accuracy against which a Simulation City approach would be compared might be measured by a 20 percent average variation of simulated data from observation. At this level, Simulation City data would be as effective as data prepared by standard methods, and probably would lead to erroneous decisions in no more than 30 percent of all cases. This guideline is useful only in the absence of better information, for it is based upon observations of models and decisions which are not necessarily comparable. In the particular context of this study, there is little basis for believing that the GEM model will behave like standard transportation models. Further, only design questions have been treated, and nothing has been said about policy-related questions.

LOSSES IN ACCURACY THROUGH THE SIMULATION CITY APPROACH

The above discussion was directed at establishment of baseline information on data accuracy, relative to its impact in decision-making. The next step is to investigate what losses in accuracy might result from utilization of a Simulation City approach.

Alonso's discussion of data[38] is instructive. He bases his discussion on a formula which relates error in output to errors in input, when applied to some predictive model $Z = f(x_1, x_2, \ldots, x_n)$:

$$e_z^2 = \sum_{i=1}^{n} f_{x_i}^2 \, e_{x_i}^2 + \sum_{i=1}^{n} \sum_{\substack{j=1 \\ i \neq j}}^{n} f_{x_i} \, f_{x_j} \, e_{x_i} \, e_{x_j} \, r_{ij}$$

where:

e_z = error in the predicted variable (z)

f_{x_i} = partial derivative with respect to input variable x_i

r_{ij} = correlation between variables x_i and x_j

This equation is exactly correct only in the event that the function $f(x_i)$ is linear, but is a good approximation for many cases.[39]

Using this approximation, it may be seen that an increase in error in one input variable may have a relatively significant influence upon overall prediction error, if the input variable is correlated with others. Large scale planning models are more likely than not to have such correlation. If the errors in all input variables increase by the same proportionate amount, then the error in prediction will increase by this same proportion. This condition suggests that the upper limit of

loss of accuracy due to increased error in any one or more input variables is equal to the maximum increase in error in any one of the variables.

If a Simulation City model can reconstruct a city data base to within a 20 percent range of error relative to standard data, for example, then one might expect at most a 20 percent increase in error or uncertainty in the predictions of the planning model for which the data were prepared. That is, it may be expected that the final results of the modeling process would exhibit no greater loss of accuracy than that of the most poorly simulated variable in the Simulation City model.

The degree to which the overall loss in accuracy would be less than this maximum would depend upon the planning model with which the Simulation City model is linked. If the model is relatively sensitive to variations in particular variables, then it is desirable to minimize levels of error in these variables.

As will be seen in discussion of Simulation City design in the appendices, the conceptual descriptions of computational sequences commence with those data items which are better understood and which may thus be simulated with greater accuracy. For example, models to predict trip length will typically account for greater than 90 percent of the variation in observed data.

Regression studies such as those cited in Chapter II have developed models for socio-economic factors which generally account for 60 to 90 percent of observed variations in variables. These variables are included at the second stage of Simulation City procedures. Items treated in the last stages of the simulation are typically those for which there is little background information or for which results have been poor.

ACCURACY AND COST IN THE GEM CONTEXT

As a test case, implementation of a Simulation City model for input to the GEM model presents a number of difficulties. One of the principal ones among these is that GEM is a new model, with relatively little history of application. It is not clear to what variables GEM may be most sensitive. Further, GEM utilizes an abstracted, representational data base; it is thus unclear what meaning inaccuracies introduced by a Simulation City approach might have.

Finally, the GEM model is planned to be among the most comprehensive planning-analysis models in existence. It requires a wide range of data, much of which may be difficult to obtain by standard collection procedures. A Simulation City model, if implemented to supply a large portion of this data base, will represent a severe test of the Simulation City concept.

Because of the lack of decision-making experience with GEM, there is a tendency to assess the accuracy and cost of a GEM-linked Simulation City model with respect to either the real metropolitan area, directly, or the abstracted data base normally prepared for GEM. In the former case, as has been pointed out throughout prior discussion, one is really asking more of the simulation than it purports to deliver. In the latter case, there are many aspects of the data which contain a measure of the judgment of personnel preparing the data base. Hence, it may be unclear what are the sources and resolution of discrepancies between standard and simulated data.

In contrast to these difficulties, it is clear that GEM is intended to be used at broader policy levels, and not for operational analysis of urban environmental systems. A much higher level of inaccuracy might then be tolerated in a Simulation City model, and there is much greater incentive to reduce data costs.

As was stated previously, it has been estimated that data preparation for a moderate to large sized metropolitan area (0.5 to 1.5 million people) would require approximately $30,000. It is currently estimated that approximately $60,000 would be the cost of implementation and preliminary testing of a Simulation City model for GEM. The cost of application of the simulation to prepare a data base might then be approximately $5,000. There is thus a fairly significant saving to be realized if a Simulation City model is implemented and widely applied.

It would seem quite important, however, that any judgment on the Simulation City concept be made within a context of the total GEM system. Within the context of a particular application, a Simulation City model could be quite useful. However, maintenance of the context of application is critical.

SECTION VI

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SECTION VII

APPENDICES

APPENDIX A

SIMULATION CITY APPLICATION FOR GEM: AN ILLUSTRATIVE DESIGN*

As was explained in the body of the report, one of the motivating factors for this study of the Simulation City concept has been the possibility that the concept might be applied within the context of the Environmental Protection Agency's on-going work on GEM, the General Environmental Model. A preliminary design for such a Simulation City model serves as an illustration of the entire concept, its various problems and possibilities.

One difficulty with the use of a GEM-linked model as an example is that GEM itself differs in a number of ways from typical planning models: First, the representation of geographic features in GEM currently is based upon a square grid. All roads must follow the straight edges of square parcels measuring one mile along the edge. These one square mile parcels are the minimum land unit size, and may have only one major type of land use per parcel. All economic components of the metropolitan system are represented in discrete units -- population, employment, production, consumption -- albeit they are small relative to total city activities.

On the other hand, by making such approximations, it has been possible to expand the purview of GEM, to make it one of the more comprehensive models of urban systems activity currently available. The design and implementation of a Simulation City model to "feed" GEM thus represents an extremely broad and relatively severe test of the concept, and will bring into focus the limits to which the simulation may be pursued.

*Throughout this discussion, a preliminary knowledge of the GEM characteristics and intent is assumed.

GENERAL APPROACH

As stated above, GEM representation of a metropolitan area is in terms of discrete valued variables, i.e., measured in discrete, whole units. In the case of such variables as population and employment, the units are small relative to the entire system, so that no major problem is created. Spatial distribution of activity, however, is expressed in terms of the standard land parcel, upon which there may be only one type of land use. Densely settled areas, particularly central cities, are thus not well represented, although it is unclear, on other than intuitive grounds, how seriously the error influences model performance.

Because the GEM representations are unlike those used in many other planning models, there is a major question to be answered early in the design of the Simulation City model: Should simulation be carried on in the format required for GEM, or should a more general format be employed and data then adjusted to fit the required format? The decision was made to try to follow the latter course, to provide more versatility in the simulation. On-going study and revision of the GEM system makes such versatility especially desirable. But it must be recognized that this versatility may be achieved at some expense in efficiency. Ideally, the Simulation City model would be closely matched to the planning model to which it provides input.

Figure A-1 illustrates the conceptual design for a GEM-linked Simulation City model.* As shown, the design is developed in three stages: The first stage deals with those items of data about which a relatively large amount is known, and which are generally viewed as comprising the basic socio-economic

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* The conceptual description corresponds in only a general way with anticipated computational sequences. See Appendix B for more detailed discussion of the computational approach.

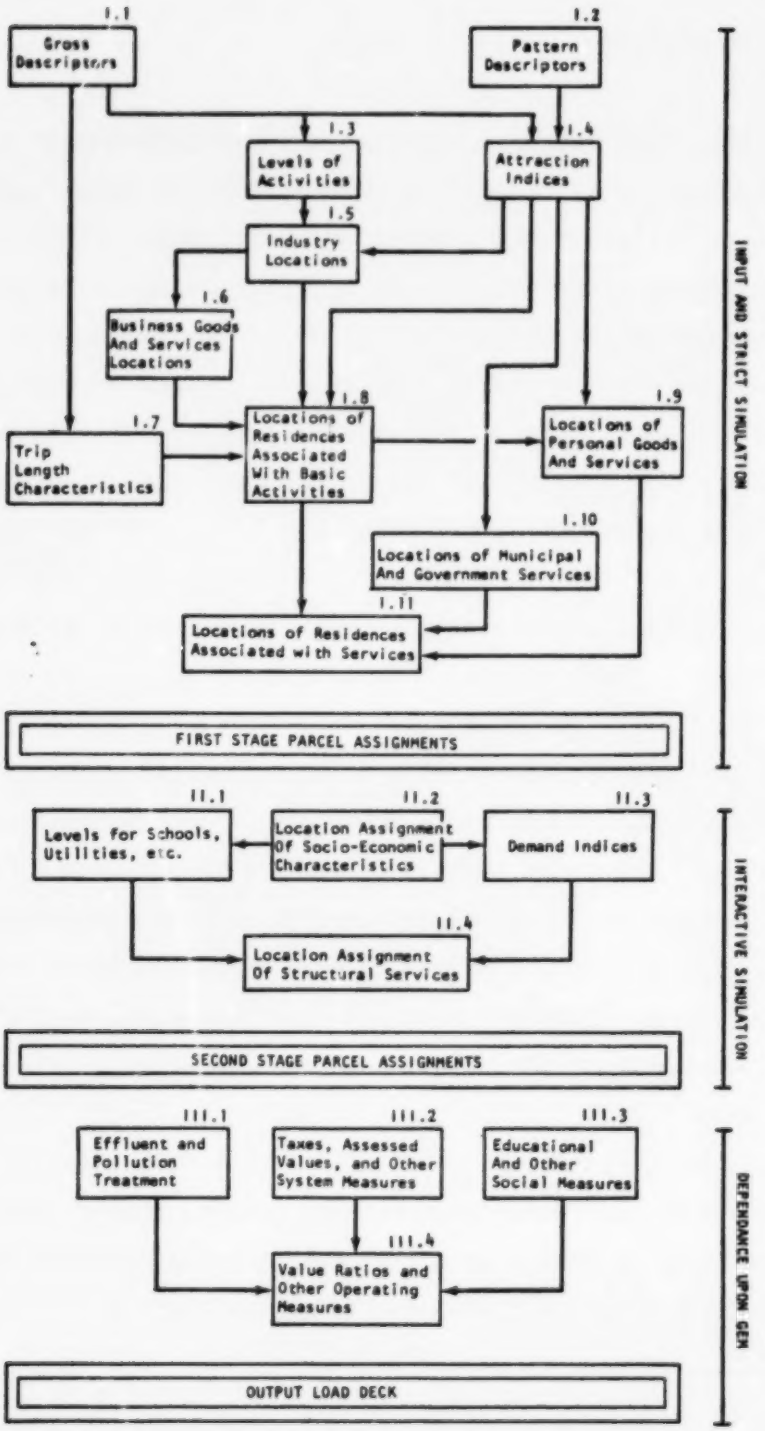


FIGURE A-1 MACRO-SCALE DESIGN OF A GEM-LINKED SIMULATION CITY MODEL

structure of a metropolitan area. In this portion of the model, all simulation would be handled within the model itself. That is, the combination of required input and information included in the model would be sufficient to permit inferences about quantities and spatial distributions of population and employment.

The second stage of the Simulation City model deals with aspects of the infrastructure of a metropolitan area. While the activities treated at this stage are always present in an area, their levels and relative locations vary widely, in response to a variety of historical, economic, and political conditions. In this stage of the model, the users judgment will be utilized to resolve questions for which current theory and empirical findings are inadequate. In this case, information will be displayed to the user, and he will be requested to make certain decisions based upon this display. For example, the locations of bus routes would be specified by the user, based upon a display of the locations of residential and employment parcels and an estimate of the number of miles of bus route that the city would have.

The third stage of the model treats a variety of data items required as input for GEM, about which there is too little knowledge to provide a reasonable basis for simulation. These items are of two types: First there are those which have not been subjected to sufficient study, and which in all likelihood could not be predicted. The pollution control technologies in use at specific sites in a city are an example of this type of item. It seems intuitively impossible to predict this information in any general way. The second type of data item is defined within the GEM system. The value ratio, for example, while quite reasonable in concept, has a limited basis for practical measurement and study. Such variables must be determined by the GEM framework itself, or specified completely by the user.

The progression of Figure A-1 may be viewed as a series of operations arrayed along a scale of trade-offs between objectivity--reflecting theoretical and empirical regularities of urban areas--and subjectivity--reflecting concepts highly abstracted from reality to accommodate the planning model. In the following pages, which discuss Figure A-1 in some detail, this trade-off will be apparent.

THE CONCEPTUAL MODEL

The following paragraphs explain, item by item, the steps of the Simulation City model presented in Figure A-1. As previously explained, this is primarily a conceptual presentation, not necessarily corresponding to the computational sequence which would be followed in an implementation of the model. Appendix B contains a more detailed step-by-step description, which is more closely related to computational considerations.

Reference is also made to Chapter II, which reviewed a substantial portion of the background literature for this discussion. An effort has been made to simplify the discussion by avoiding excessive referencing of sources and justifications of information upon which the design is based.

Input

Input for the Simulation City model is intended to represent the minimum amount necessary to yield a useful simulation. In general, an effort has been made to restrict input to those items contained in the Statistical Abstract of the United States, and USGS topographical quadrangle maps (7 1/2 minute series). The input is of two types, as shown in Figures A-1 and A-2. Gross descriptors (I.1*) refer to the overall socio-economic system which is the

* These numbers refer to the item designations in Figure 1.

FIGURE A-2

PROPOSED INPUT TO SIMULATION CITY MODEL

	Social	Political	Economic	Physical
Gross Descriptors	School enrollment Student-teacher ratio* Public assistance payments	Local government employees Bus company type*	Median income Distribution of family incomes Manufacturing employment Wholesale employment No. of housing units, total and central city % of housing in single unit structure and central city Median value, single family housing City budgets Industrial cluster City type Tax types* Unemployment rate Mean rent Annual payrolls	Total population Population density, total and central city Fraction of workers using public transit Mean trip length*
Pattern Descriptors	Count of schools, per parcel* Parks	Jurisdictional boundaries	Locations of industrial concentrations* Dense activity parcels	Highways Rail terminals* Rivers Surface water (lakes, ocean). Major facilities (airport, harbor)* Subway-rail system Non-developable land Water intake, outflow points

*Will not be required, but very desirable.

without reference to the specific geography of the metropolitan area. Pattern descriptors (I. 2), in direct contrast, are intended to convey the historical and geographic characteristics which have been instrumental in shaping the present form of the area. The analogy might be made that pattern descriptors are related to the skeleton, while gross descriptors are related to the levels, distribution, and conditions of sinews encompassing the skeleton.

Gross Descriptors (I. 1) - Several aspects of the city's economic and social system are included in the category:

- Spatial variation in activity intensity - It has been observed that the density of population, industrial activity, and commercial activity in a metropolitan area--and perhaps such factors as land value, as well--may be estimated as a function of distance from the center of the city. The form for such estimation will be the exponential function,

$$a(d) = A_{o_{a(d)}} e^{-\gamma d}$$

  where a(d) is the density of activity at distance d, $A_{o_{a(d)}}$ is a measure of the density at the center, γ is the rate of decrease of density. Alternatively, it has been observed that certain activities, primarily population, exhibit a "hole" in the city center, a sharp decrease in density (see Figure A-3). In this case, a gamma function might be used, and estimation of two parameters would be adequate to to model the likely variation in activity density as a function of distance from city center. In both cases, circular symmetry of the city is assumed.

- Economic activity composition - The overall nature of a city's economy may be characterized by the proportion of its employment in manufacturing, the ratio of basic to total employment, description of the city as one of several standard types, median, income, etc. Knowledge of this overall nature will provide a basis for allocating employment, predicting price levels, and determining infrastructure needs.

- Character of service - the term "character of service" is here intended to cover a range of factors such as infrastructure, school and governmental quality, education of

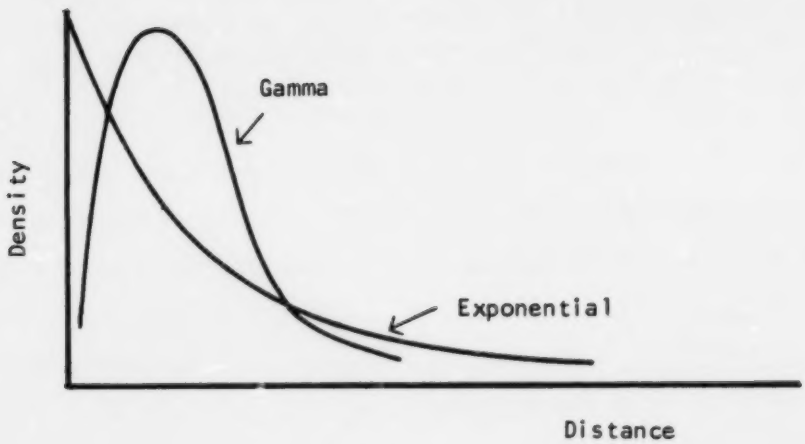
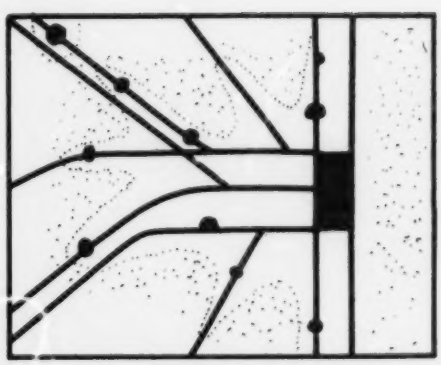
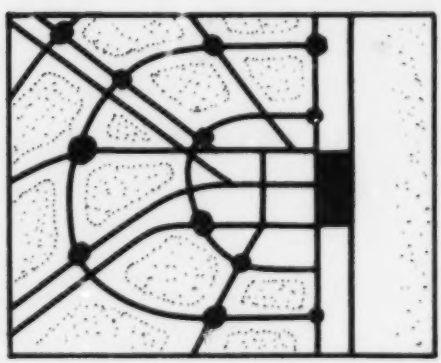


FIGURE A-3 VARIATION OF ACTIVITY WITH DISTANCE FROM CITY CENTER



Radial Arterial-Oriented
Early Metropolis



Grid Arterial-Oriented
Mature Metropolis

FIGURE A-4 HISTORICAL PATTERNS OF URBAN FORM BASED UPON TRANSPORTATION GROWTH

the populace, income ranges, and amenities provided to the populace. Simple regression models will be employed to predict likely levels of sewer service and cost, parks and recreational facilities, educational expenditures, transportation levels of service, etc.

Through considerations such as these, the scales of various components of the metropolitan system are estimated. Within the Simulation City model, these estimates are expanded to describe more completely the city data base.

Pattern Descriptors (I. 2) - This set of descriptors is concerned with the factors of geography and history which cause each city to develop an individual form. These factors fall into several categories:

- Topographic features - rivers, major bodies of water, marsh land, harbors, flood plain
- Political-development features - City center, major government institutional development centers, major highways, rapid transit lines, sanitary landfills.
- Historical development features - Transportation development patterns (see Figure A-4), settlement orientation (the recreation versus industrial orientation, leading to dispersion versus concentration of activity).

Such locational factors are indicated within the grid which will become a mapped presentation of the city data base. The Simulation City model will proceed from these starting points, through inference, to distribute the development estimated to be present in the metropolitan area.

Estimation of Levels and Patterns

The process of expansion of basic input information into a preliminary picture of the metropolitan area has been partially described above, and is illustrated in Figure A-4. This expansion consists of two parts: the estimation of the levels of various economic activities in the city (I. 3), and the estimation of measures indicating the relative likelihood that these activities will be located in specific sub-areas in the metropolitan region (I. 4).

Levels of Activity (I. 3) - The simulation of levels of activity in a GEM-linked Simulation City model will be dependent upon the data rules of GEM itself. This operation will be one essentially of using the Master Tables directly to translate the input data. Beginning, for example, with the total population and the manufacturing employment, the number of levels of industry may be estimated. This estimate will be modified slightly, and distributed among specific industries, by income distribution. Required levels of business goods and services may be computed directly, and an allocation of population units to employment in these two categories, estimated from the census input. Similarly, required levels and allocation of workers may be estimated for personal goods and services, municipal services, schools, etc.

It will be necessary to go through the cycle more than once, in order to balance population and employment, i. e., to attain the greatest number of industrial levels compatible with the total population of the city, its distribution of income, and its type and industrial character. It is anticipated that the computational sequence may change with city size, for it is only in large cities that goods and services, as treated in GEM, begin to have significant influence on the distribution.

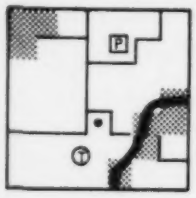
The numbers of parcels required to accommodate the city will be computed directly from the allocation of levels, subject to constraints of central city and metropolitan area population densities, jurisdictional controls, and a desire to minimize the amounts of undeveloped land within the city's built-up areas. This computation again is a relatively straight-forward application of the Master Tables.

Proceeding in this fashion, thenumber of people, level of industry, levels of employment, etc., as required for GEM, are estimated. As shown in Figure A-5, these estimates might be displayed in tabular form, providing a picture of the socio-economic system of the metropolitan area.

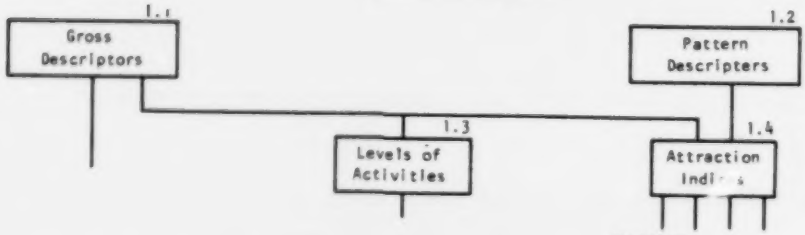
PROPOSED INPUT TO SIMULATION CITY

	Social	Political	Economic	Physical
Gross Descriptors	School enrollment Student-teacher ratio* Public assistance payments	Local government employees Bus company type*	Median income Distribution of family incomes Manufacturing employment Wholesale employment No. of housing units, total and central city % of housing in single unit structure and central city Median value, single family housing City budgets Industrial cluster City type Tax types* Unemployment rate Mean rent Annual payrolls	Total population Population density, total and central city Fraction of workers using public transit Mean trip length*
Pattern Descriptors	Count of schools, per parcel* Parks	Jurisdictional boundaries	Locations of industrial concentrations* Dense activity parcels	Highways Rail terminals* Rivers Surface water (lakes, ocean) Major facilities (airport, harbor)* Subway-rail system Non-developable land Water intake, outflow points

*Will not be required, but very desirable.



P parks
• dense activity parcels
T rail terminals
major facilities non-developable land
river
highways



MATRICES [aiA]

I= parcel number
A= activity type, e.g.
- -heavy industry
- -light industry and commercial
- -residential, high and medium
- -residential, low and medium

Activity	Constructed	Associated Population			Parcels
	Levels	PH	PH	PL	
HF	3	13*	12	12	1
NL	1	4	6	3	1
SN	2	14*	6	6	1
BG BS PG PS					*Note shortage of high income labor force... simulated from labor statistics and income.
MS SC					
RA RB					

FIGURE A-5 THE FIRST STEPS IN SIMULATION

Attraction Indices (I. 4) - The attraction index may best be understood--and will be computed--as a probability that a particular activity will be found on a particular parcel, given the information known about that parcel and its surroundings. The attraction index of a parcel (i) for an activity (k) would be computed as:

$$A_{ik} = (a_{ik} \cdot p_{ik}) S_k$$

where:

A_{ik} = an overall city measure of activity density

p_{ik} = a measure of features specific to the individual parcel

S_k = scale factor, such that $S_k = \sum_i a_{ik} \cdot p_{ik}$

The first component of the index, an overall density measure, would be derived from gross descriptors input. As explained previously, estimates of the parameters of an exponential distribution could be computed to give a predictor of the density of heavy industry activity, in a city of a particular type, as a function of distance from the center of the city. Then:

$$a_{ik} \propto D_{kt} \; e^{-\gamma_{kt} \; d_i}$$

where:

D_{kt}, γ_{kt} = exponential parameters for heavy industry (k) in a city type (t)

d_i = center-to-center distance of parcel (i) from the central parcel.

This component of the index will indicate a tendency of activities to locate centrally, with some types of cities typically having greater concentration or compactness.

The second component, a parcel specificity indicator, would be derived from pattern descriptors input. A range of considerations would be reflected in this component, as suggested in Figure A-2. The component could be formulated as:

$$P_{ik} = \left[f_{ik1} \cdot f_{ik2}\right] \left[V_{ik}\right] \left[M_{ik1} + M_{ik2} + M_{ik3}\right],$$

where:

f_{ik1}, f_{ik2} = feasibility measures indicating whether it is allowable that parcel (i) attract activity (k)

V_{ik} = a measure of the availability of space in parcel (i)

$M_{ik1}, M_{ik2}, M_{ik3}$ = measures of amenities of parcel (i) relative to activity (k).

For this specific example,

f_{ik1} = { 1 if the parcel is developable; 0 if it is not }

f_{ik2} = { 1 if there is no activity already on the parcel which conflicts with activity (k); 0 if there is such a conflict }

V_{ik} = a ratio of the percentage of undeveloped land in parcel (i) to the percentage of a parcel required for one level of activity (k)

M_{ik1} = access measure, the product of the number of sides of the parcel having highway access multiplied by the average level of the highways.

M_{ik2} = Quality measure, a defined scale giving value to the presence of complementary features on the parcel

M_{ik3} = environs measure, a defined scale giving value to the presence of complementary or conflicting activities or features within the parcels immediately adjacent to parcel (i).

As a minimum, there would be two attraction index matrices, one for industry and commerce, and one for residences. It is likely that in larger cities there would be one each for heavy and light industries, low income residential, and goods and services.

Attraction indices would be modified as each activity is allocated. In the above example, parcels would have changes in f_{ik2} and M_{ik3}, dependent upon the sequence of assignment. Figure A-6 illustrates this recomputation.

It is anticipated that some research would be required to implement this component of the Simulation City model. Standard regression analysis would be utilized to develop attraction indices equations of the types described above.

Location of Activities

Actual simulation of the form of the metropolitan area begins with the location of activities. Generally speaking, the Simulation City model will distribute the previously estimated levels of socio-economic activity over the grid of the metropolitan area, in accordance with the previously computed attraction indices and various rules derived from theories of urban growth. Figure A-6 illustrates aspects of the procedure, which will start with the location of industry.

Industry Locations (I.5, I.6) - As mentioned in Chapter II, basic industry is generally viewed as the central force in the metropolitan system, from the standpoints of both economics and locational patterns. However, research into the causal factors influencing location of basic industry has not been noticeably successful. Hence, designation of parcels containing basic industry is not an especially promising candidate for simulation, particularly in view of the GEM constraint of one land use per parcel. It would be preferable for

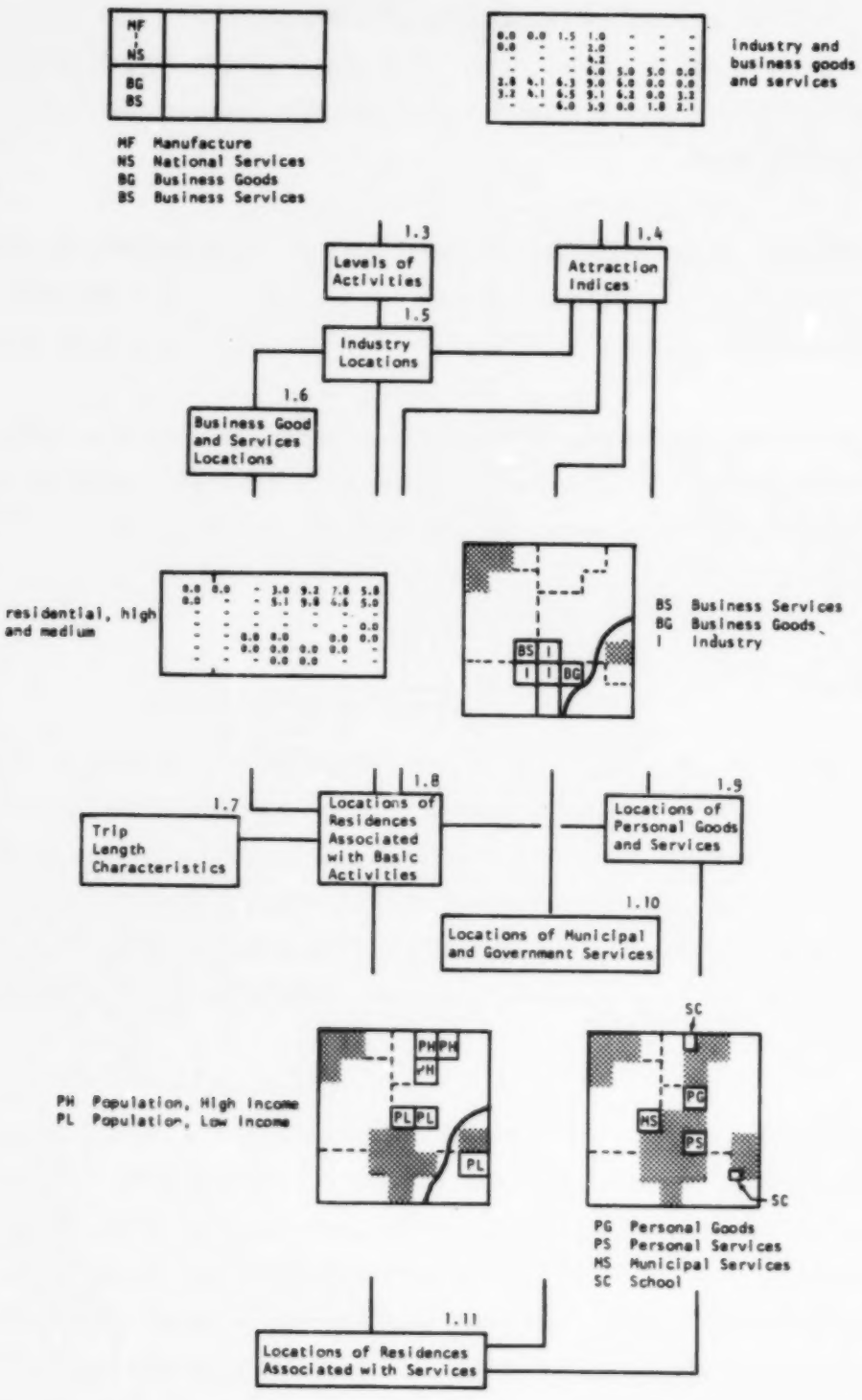


FIGURE A6 ASSIGNMENT OF LOCATIONS

the user to designate these parcels, based upon a knowledge of the metropolitan area.

In the absence of this knowledge - as a default measure - the attraction index matrix for business goods and services might be modified to include basic industry, which would be assigned in the same manner as other activities.

The manner in which activity will be located is by selection of those parcels having the greatest attraction indices, up to the required number of parcels estimated previously. Figure A-6 illustrates this procedure, for six industrial and commercial parcels. Levels of activity on individual parcels will be allocated in proportion to the values of the attraction index in that parcel, subject to the constraint that each parcel have at least one level of its assigned activity.

Residential Locations (I.7, I.8, I.11) - Residential locations will be designated in basically the same fashion as industrial and commercial (business goods and services), via the selection of parcels having the greatest estimated attraction indices. However, residential attraction indices will be computed differently from those for industry.

First, as illustrated in Figure A-6, the GEM constraint on land use requires that residential attraction indices be identically zero for parcels previously allocated to another land use. However, it would be expected that only in dense, inner city areas would this constraint produce conflict.

A more significant modification would be made to account for travel distance. As mentioned in Chapter II, the location of residences would seem theoretically and empirically to be influenced by a desire to minimize the journey

to work. The Lowry model and its successors, which Wilson has termed "entropy maximizing" to indicate the character of the models as optimum estimators of patterns of location, have been based largely on the journey-to-work as the basis of residential location.

Based upon the Lowry model type of formulation, residential levels would be allocated using the following formulation:

$$P_{iR} = \sum_{j} T_{ij}$$

where

P_{iR} = residential population potential of parcel (i)

T_{ij} = number of people (potentially) living in i and working in j.

A solution is found for the expression:

$$T_{ij} = W_j \, (E_{jI} + E_{jB}) \, A_{iR} \, e^{-\frac{2d_{ij}}{\delta}}$$

where

A_{iR} = residential attraction index of parcel (i)

$E_{jI} + E_{jB}$ = number of employees in industry and business goods and services on parcel (j)

d_{ij} = effective distance between parcels (i) and (j)

δ = mean trip length for work trips in the area

$1/W_j = \sum_{i} A_{iR} \, e^{-\frac{2d_{ij}}{\delta}}$, a normalizing factor;

subject to the constraint that:

$$\sum_{i} T_{ij} = E_{jI} + E_{jB},$$

i.e., the total number of potential trips to a parcel (j) is equal to the number of employees in that parcel. This solution then permits computation of P_{iR} for each parcel. Parcels having the greatest values of P_{iR} are selected, up to the previously estimated required number; and levels are allocated in proportion to this population potential.

In large cities, it may be desirable to perform this allocation on a stratified basis, by income group. In this case, the above model would be applied consecutively to each group with changing estimates of attraction indices and mean trip length.

Obviously, a major component of these models is trip length. The travel characteristics of a population are represented by a relative frequency distribution of trip lengths; and it is found that this distribution varies with trip purpose, socio-economic characteristics of the trip-maker, and characteristics of the transportation system.

As mentioned in Chapter II, it has been found that the distribution of trip length may be approximated by the gamma distribution, specified by the mean trip length. Hence, gross descriptors will be employed to estimate mean trip length(s). City size, city type, and income distribution, would be three parameters of major importance in this estimation.

Thus, using the Lowry model approach as a basis, residential locations will be designated, and levels assigned, relative to previously located industry and commerce. As Figure A-6 illustrates, this location could be done in two stages, with personal goods and services assigned in relation to industry-associated residences. Service residences would then be allocated with respect to distance from this portion of commercial activity. Municipal and other governmental services will be treated with personal goods and services.

Associated Services

The above paragraphs describe the progress of the GEM-linked Simulation City model, through the first stage parcel assignments indicated in Figure A-1. This first stage of assignments represents the aspects of a metropolitan system about which a relatively significant amount is known. As has been explained, in the second stage of assignments, an interactive approach would be employed, an approach intended to make use of the user's judgment in areas where rational predictive rules cannot be formulated. Figure A-7 illustrates this approach, for the case of bus routes.

As was mentioned in Chapter II, it may be possible to estimate the total levels of various services in the city. These totals would then be displayed to the user, to be assigned by him to particular sub-areas. The vehicle for this assignment would be a status map, a display of particular aspects of the simulation up to that point. Information displayed on the status map would, in effect, define a spatial pattern of needs for services, allowing the user to judge how needs are to be filled. In making this judgment, the user can bring to bear all of his knowledge of actual conditions in the area, to provide the GEM representation with as great a similarity to reality as may be possible.

The approach to estimation of levels of services (II. 1) will be the same as that for major activities, discussed previously. These levels represent maximum amounts of these services which might be available in the metropolitan region.

The demand indices (II. 3) would reflect an estimation of where these services are most likely to be available. For example, rent and income levels in residential parcels will be estimated (II. 2), and together with job location, would be of use in locating bus routes. The status map would then display

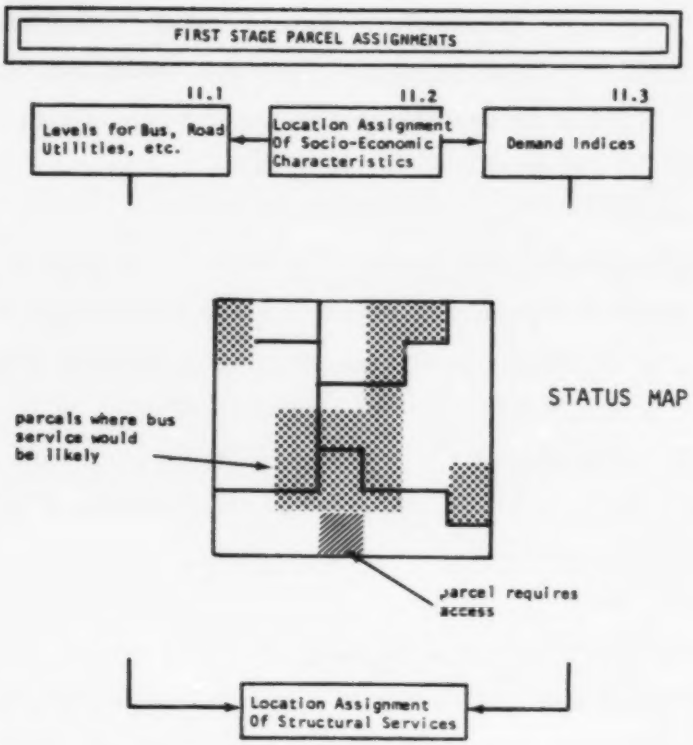


FIGURE A-7 INTERACTIVE STAGE OF A GEM-LINKED SIMULATION CITY MODEL

the parcels containing high likelihood-of-service activity, along with the available roads linking these parcels. The user would then designate route location, up to the limit of mileage estimated by the Simulation City model, as illustrated in Figure A-7.

Figure A-7 illustrates another aspect of this interactive stage of the simulation. Because only the major highways are required to be input by the user, location of activity in the first stage of the simulation will not be absolutely constrained by the presence of access to a parcel. Thus it is possible that in the second stage of simulation there would be parcels with activity and no access to other parcels. Such parcels would be displayed on a status map, for the user to designate a preferred access route.

Proceeding in this fashion, this Simulation City model will provide a basis for the user to complete the description of a city's physical structure, in terms of a GEM data base. The remaining data required for GEM, dealing primarily with socio-economic conditions and pollution services, will be treated in a third stage of the model, dependent heavily upon user knowledge and judgment.

Operating Measures

The GEM model requires as input a number of data elements which are especially difficult to treat in simulation, or which have a definite meaning only within the GEM context. These items - such as value ratios, tax rates, pollution control technologies, costs of goods and services outside of the metropolitan region - refer primarily to operating characteristics of the city, and have not been submitted to sufficient analysis to exhibit any promise that their prediction would be feasible. The Simulation City model will thus depend upon user input for these items, until such time as research can be undertaken to develop the necessary data.

As a default measure, the GEM-linked Simulation City model will include standard values, or procedures for setting such values, for all remaining items in the GEM load deck. It must be recognized, however, that this is not a realistic simulation, relative to the previous stages of the model. It is simply a stop-gap measure, intended to maintain the accessibility of the GEM system for use on a broad range of policy-related questions.

SUMMARY OF THE GEM-LINKED MODEL

This chapter has provided a broad overview of a proposed application of the Simulation City concept - a model to provide input to the General Environmental Model. The GEM-linked Simulation City model is formulated in three stages, representing decreasing knowledge of underlying relationships describing a metropolitan area, and increasing dependence upon the rules inherent in GEM itself.

The purpose of this overview has been two-fold: first, it has addressed directly the manner in which a GEM-linked model might be constructed (see Appendix B for more details), and has thus indicated the extent to which such a model may be feasible to implement. Second, it has provided an example of the Simulation City concept as a whole, and thus provides insight into feasibility on a more general level.

The following chapter examines aspects of the cost and accuracy of Simulation City data, and thus addresses more directly the question of feasibility of the approach. This question is one of more than simply technical capability, but of cost and effectiveness as well.

APPENDIX B

A SIMULATION CITY MODEL FOR GEM: COMPUTATION-ORIENTED DESCRIPTION

Appendix A gave a general description of a GEM-linked Simulation City model. This Appendix is intended to describe the design in a step-by-step manner, and thus to provide a basis for complete design and implementation of the model. Figure B-1 illustrates how the computational steps presented here fit into the previous discussion. Appendix C accompanies this description by presenting the GEM load deck as it will be treated by the Simulation City model.

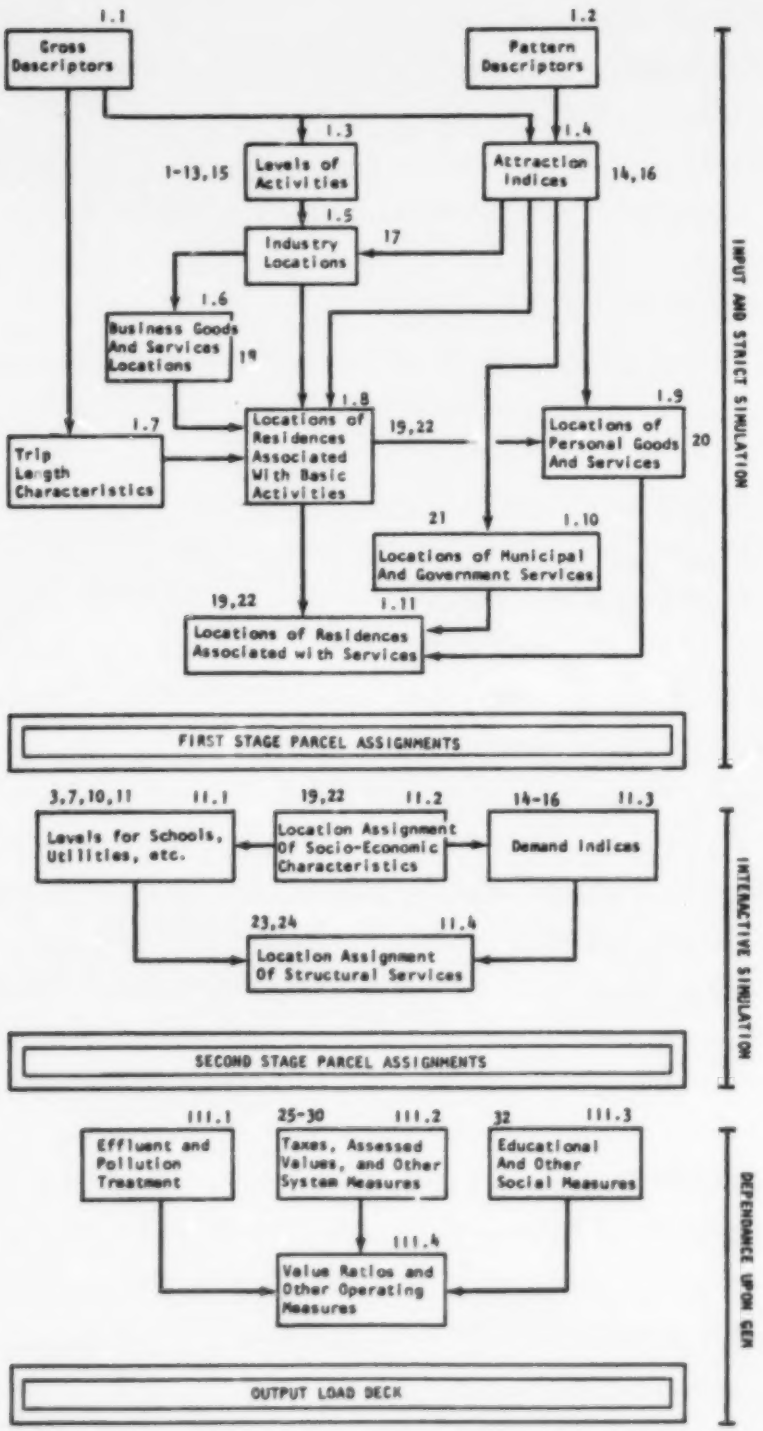


FIGURE B-1 MACRO FLOWCHART FOR SIMULATION CITY

1. Determination of Population Levels

Total Population*, compared with a Master Table value, determines the total number of P1's in the city.

Median Family Income and the Distribution of Family Incomes are used to split this total of P1's into PL, PM, and PH.

2. Determination of Levels of Industries

Manufacturing Employment is used to estimate the total number of levels of industry activity (including NS), leaving workers to be allocated to goods and services.

Selection of one of several Standard Industry Clusters or designation of a Percentage Distribution by the user determines the number of constructed levels of specific activities.

3. Determination of School and Teacher Levels

School Enrollments and an indicated Student-Teacher Ratio (a default will be available) are used to estimate the number of levels of teachers. Percentage of Local Government Expenditure on Education and the distribution of population by income (1)* are used to split these levels between PM and PH.

The computed numbers of students from the Master Table and the distribution of population by income (1), and the number of levels of teachers are used to determine the number of constructed levels of schools.

4. Determination of Constructed Levels of Housing

The Numbers of Housing Units, Total and Central City, and the Percentages of One Unit Structures, Total and Outside Central City, are used to estimate the percentage of housing levels in RA. The Central City

---

* Underlining indicates a direct input item. Numbers in parentheses refer to other steps in the simulation.

Population Density is used to estimate the split between RB and RC.

The distribution of population levels by income (1) provides an estimate of space units demanded, thus permitting estimation of the constructed levels of housing.

5. Determination of Municipal Services

The numbers of levels of industry (2), housing (4), and personal goods and services (8); preliminary estimates of business goods and services (derived from industry levels); and the Number of Local Government Employees are used to estimate the number of levels of municipal services. PL and PM employment levels are assigned to these services.

6. Estimation of Housing Conditions

The levels of constructed housing (4) are allocated to population levels by income (1), using standard allocations and a comparison of Median Family Income and Median Value of Single Family Housing.

7. Determination of Utilities Levels

Housing conditions (6) and the levels of industry (2) are used to estimate requirements for power, water treatment, and solid waste. Constructed levels of these activities are then estimated to provide for these requirements.

8. Determination of Levels for Personal Goods and Services

Housing conditions (6) and population levels (1) are used to estimate constructed levels of PG and PS. PH, PM, and PL worker units are assigned directly to these goods and services.

9. Determination of Business Goods and Services

Levels of industry (2), personal goods and services (8), residences (4), schools (3), municipal services (5), public transport (13, 14), and highways (11) are used to estimate the constructed levels of BG and BS.

Levels of PH, PM, and PL workers are assigned directly to these goods and services.

10. Determination of Levels of Terminal

Industry (2) and business goods (9) are used to estimate the constructed levels of terminal. Central City Population Density and area are used to estimate the number of terminal locations.

11. Estimation of Minimum Highway Levels

Levels of population (1), bus service (13), business goods (9), and industry (2) are used to estimate a minimum number of levels of highway service required in the region.

12. Determination of Industrial Employment

Population distribution by income (1) is compared with labor allocations made previously (3, 5, 8, 9, 13) to determine the number of units remaining. These remaining levels are allocated to industry in proportion to demand (2).

13. Determination of Bus Services

Central City Size and Density, and the Percentage of Workers Using Public Transport are used to estimate the miles of public transit route. Units of PM labor are assigned directly to meet the required levels. Rail Rapid Transit is subtracted from the estimate, leaving an estimate of miles of bus route.

14. Estimation of Overall Density Measures

Total Populations and Population Densities in central city and total SMSA are used to estimate the parameters of an exponential distribution. This distribution gives a first approximation of the density of industrial and population development in the region.

15. Determination of Numbers of Parcels

The parameters of the exponential distributions (14), the levels of housing (4), and goods and services (8, 9, 5) will be used to estimate the number of parcels (equivalent) to be allocated. These estimates give guidance for limiting the size of subsequent computational operations.

16. Estimation of Expected Activity Rates

The Input City Pattern and the exponential distribution (14) are used to estimate the expected intensity of industrial-commercial and residential land use activity within parcels. Adjustments will be made to permit location of access to parcels where none is provided in the input.

17. Determination of Industry Locations

Parcels containing basic industries will be Indicated by the User or selected as those having the highest expected activity intensities (16), up to the limit of number of parcels previously estimated (15). Levels will be assigned in proportion to expected activity intensities (16).

18. Determination of Business Goods and Services Locations

Parcels adjacent to industry locations (17) and having high expected activity rates (16) are selected as locations for business goods and services. Levels are assigned to approximate overall density estimates (14).

19. Determination of Low and High Income Residential Locations

Expected activity rates (16) for residential parcels are modified to account for industry-commercial locations (17, 18), and for Mean Trip Length. PL population will be distributed by housing type (6). PH parcels will be designated, and levels distributed by housing type using a different set of rates. Population densities on parcels will be assigned up to the proportion of the appropriate income class within the total population (1).

20. Determination of Locations for Personal Goods and Services

Location of the estimated number of parcels (15) will be made adjacent to residential locations - PL and PH (19) - according to industrial activity rates (16).

21. Determination of Locations of Schools, Municipal Services, and Utilities

Locational assignment will be made to va cant space in previously assigned parcels (17, 18, 19, 20), or to immediately adjacent developable parcels. Water Intake and Outflow are assigned by user.

22. Determination of Location of Medium Income Residential Parcels

PM levels are assigned, by housing type (6), to vacant land on previously designated residential parcels (19), up to expected activity rates (16, 19). Additional parcels are selected as necessary, up to the total parcels estimated for the city (15).

23. Provision of Additional Required Access

The distribution of activities is displayed to the user, with an indication of parcels requiring access. If input mileage is below estimated minimum required (11) the deficiency is noted for user action.

24. Location of Bus Routes

Distributions of residences and jobs will be displayed, for user assignment of bus routes, up to the previously estimated mileage (13).

25. Determination of Public Transit Fares and Salaries

City Budgets, Bus Company Type, and Median Income will be used to set fares and salaries. Relations between bus and rail fares, when both are applicable, will be set relative to national experience.

26. Determination of Salaries

Payrolls, by activity, and Median Income will be used to set the salary scale for industry and commerce.

27. Determination of Rents

Mean Rent and the Distribution of Income will determine rent levels. Assignment of rents will be based upon distance from the center and density of population (19, 22).

28. Determination of Prices

A standard price structure will be applied, adjusted to Median Income.

29. Determination of Assessed Values

Assessed values of parcels will be computed by capitalizing prices and rents (27, 28).

30. Determination of Government Transfers

Taxes and unemployment payments will be set by application of standard structures, adjusted to City Type, Tax Type Indicators, Unemployment Rate, and Public Assistance Payments.

31. Determination of Zoning

Zoning will be set to be consistant with assigned activities (17, 18, 19, 20, 22).

32. Determination of Educational Levels

Educational levels will be determined by previously assigned rents and income characteristics (19, 22, 27).

APPENDIX C
THE GEM LOAD DECK

Following is a list of items in the GEM load deck, which are to be treated in the Simulation City model. Appended to various items to be treated are brief comments to indicate sources of information or computational procedure. Acronyms and variable names correspond to GEM usage, and the reader is referred to forthcoming EPA reports for their discussion.

Land Parcel Cards

6	12-14	Constructed Level of Economic Activity	a) Manufacturing levels from Statistical Abstracts and Master Sheets for Economic Sector b) Residential levels from Statistical Abstracts which give RA level. RB and RC will be calculated from area density c) Pa, Ps levels from population levels and housing levels d) Ba, Bs levels from levels of industry, Pa, Ps, residences, schools municipal services, utilities, consistent with activity.
	15-17	Zoning	
	18-21	Value Ratio	
	22-25	Maintenance Level	
	30-33	No PH Residing on Parcel	Person levels are split by income type and assigned to parcels using attraction indices for (PH, PM) and (PM, PL)/ Attraction indices are calculated from city density, highway, rivers, undeveloped land, industry location, mean trip length, etc.
	34-36	No PM Residing on Parcel	
	37-39	No PL Residing on Parcel	
	40-43	Salary PH/$100 if non resident. Rent per space unit if resident	Salary for PM from median income in Statistical Abstract. PH taken to be 1 1/2 x median income, PL taken to be 1/3 median income. Similarly, rents are computed from statistical Abstract median rent
	44-46	Salary PM/$100 if non resident. Rent per space unit if resident	
	47-49	Salary PL/$100 if non resident. Rent per space unit if resident.	
	54-56	Level of Utilities installed	Use utility units from Rent Master sheets
	60-67	Price/CU in $100	Mean income, location population, industry, Ba, Bs, Pa, Ps.
	68-75	Assessed Value of land/$100,000 for all parcel	Prices, rents, location

	77-78	If industry on parcel Effluent treatment type	
	80	Treatment plant level	
	1-5	Parcel Good	Map
	7-8	Team letter of owner	
	10-11	Economic Activity Code	e.g., MF, Ba, RA. The activity is assigned to parcel using attraction indices Industry assigned first Ba, Bs. RA, RB, RC by income type Pa, Ps, schools, municipal services, utilities.

Water Intake Plant and Undeveloped Land

8	1-2	WA	
	3	Jurisdiction no	
	11-15	Parcel location	From map
	16-17	Level of intake treatment plant (0 if under land)	Constructed levels industry etc, required level
	18-20	Percent of parcel (developed and undeveloped) owned by Water Authority	

School Cards

9	1-2	SC	
	3	Jurisdiction	
	11-15	Parcel Location	Schools located centrally
	16-17	Level of School	Statistical Abstract students School quality teachers with school master sheets school level
	18-20	% owned by dept.	
	21-23	Value ratio	
	24-26	Maintenance level	
	27-29	PM teachers (in P1's)	See above
	30-32	PH teachers (in P1's)	

Terminal Cards

10	1-2	TM	
	3	Jurisdiction	
	11-15	Intersection coord.	Use map to decide location
	16-17	Level	From levels of industry, etc and using Master Sheets
	18-20	% land used by terminal on each of four parcels surrounding intersection	Determined by user

Park and Public Institutional Land

11	1-2	PZ or PI	
	3	Jurisdiction	
	11-15	Parcel containing parkland	From map
	16-20	Percent of land in park or public institutional use	From map

Municipal Services

12	1-2	MS	
	3	Jurisdiction	
	11-15	Parcel location	Located centrally
	16-17	Level of plant	Levels of industry, etc, give level of MS based on Master Sheets
	18-20	% land owned by department	
	21-23	Value ratio	
	24-26	Maintenance level	
	27-29	PL workers	From Master Sheets
	30-32	PM workers	From Master Sheets

Road Cards

13	1-2	RD	
	3	Jurisdiction	
	11-15	Intersection where road segment begins	From map

	16	Direction	From map
	19	Road Type	
	23-25	Value ratio of road segment	

Undeveloped Highway Land

14	1-2	HR	
	3	Jurisdiction	
	11-15	Location	Any land available after all assignments?
	16-20	% parcel owned but undeveloped	

Municipal Services Salaries

16	1-5	PL salary in $100	Fraction of Median Income
	6-10	PM salary in $100	Median Income from Statistical Abstract

School Salaries

17	1-5	PM salary	Median Income from Statistical Abstracts
	6-10	PH salary	Factor x Median Income may modify Government expenditure on education
	11-15	Middle class part-time units for adult education and employment	
	16-20	High class part-time units for adult education and employment	

Bus Salaries

18	1-5	Salary offered by Bus company/$100	Bus use-company type, city budget and mean income
	6-10	Salary offered by Rail company/$100	Bus fares, bus salary give rail salary

Bonds

19	1-2	Department name	
	3	Jurisdiction	
	4-5	Interest rate in 1/10%	
	6-7	Remaining term	
	8	"0" if current bond (2 (2 yr.) "1" if capital bond (25 yr.)	
	9-14	Amount/$10,000	

Taxes

20	1	Jurisdiction	1
		Land	Mean Income and Tax designator provide general tax structure
		Building	
		Resident-Income	
		Employment Income	
		Resident Auto	
		Employment Auto	
		Personal Goods	
		% bid price for land bid	
		% above value for outside construction	

Rents

23	1-5	Location	(See Land Parcel Cards - 6)
	6-10	Rent/space unit	

Bus Routes

24	1-3	Level of service	City size, density, area miles of bus route
	5	1 for bus	
	6-10	Route No	Activity map assigned bus route

Detailed Route Invormation

	1-5	Starting point	
	6-10	Location of turn of end point	

Rail Stations

25	1-5	RLSTA	
	6-10	Number stations on board	Subway map
	11-15	Location	

Unused Rail Land

26	1-5	RLLND	
	6-10	Twice the no. of parcels on this card	
	11-15	Parcel location	
	16-20	% of land owned by RR department but unused	

Track Segments

27	1-5	RLTRK	
	6-10 11-15	Intersection pair which defines segment	Subway map or USAS map
	16-20	Location of parcel over which any part of segment is above ground	Subway map or USAS map

Rail Routes

28	1-3	Level of Service	
	5	"0" for rail	
	6-10	Route No.	
	11-15	No. of turns and/or stops	

Additional Cards for each Rout e

	1-5	Intersection of stop or turn

	10	0 if stop or stop and turn 1 if turn only	
Ba/Bs Contracts			
29	2-7	Cards per department	
Bus/Rail Fares			
31	5	1 for rail 2-bus	Set by Median income, bus company type, and city budget
	6-10	Base fare in cents	
	16-20	Increment/mile	
	21-25	Value ratio of equipment	
	26-30	Maintenance Level	
Highway Maintenance Levels			
32			
Education Level			
33	1-5	Parcel location	
	6-8	Education Level - high class	Standard table for city types
	9-11	Education Level - middle class	
	12-14	Education Level - low class	
Welfare Payment			
34	1	Jurisdiction	
	2-6	Welfare Payment per unemployed worker in $100	Statistical Abstracts
Prices for Outside Purchase			
35	1-10	Price/CU for outside Pa, Ps	
	11-20	Price/CU for outside	
	21-30	Price/MA for outside water	
	31-40	Price/MA for outside water for residents and private utilities	

	41-50	Price /ton solid waste dump	
	51-60	Price EPU for EPU shortage	
	61-65	Multiplier for cost to SWC to provide level 2 service	

Topographical Restrictions and Pre-Empt Land

36	1-2	Row No. (12-60)	
	6-8	Three column per board	From map
	up to 78-80	Square for given row containing % square undevelopable	

Government Employment Locations

37	1-10	Rail	
	similarly BUS MS 1, SC 1,		as with industry

Federal State Employers

38	1-5	Location	
	6-10	PL job openings	
	11-15	PM job openings	
	16-20	PH job openings	
	21-25	PL salary	Government salaries in Statistical Abstracts
	26-30	PM salary	
	31-35	PH salary	

Surface Water

39	1-5	Location	Map
	6-10	Volume in MaD	
	11-13	% land area	Map
	14-15	Rate of flow (parcels/day)	
	16-20	Next parcel water flows into	Map

Lake Parcels

40	1-5	Location	Map
	6-10	Water Quality	

Municipal Treatment Plant

44	1-5	Location	From Map
	7-8	Outflow type	
	9	Level	From level of industry, etc, and Master Sheet

Intake and Outflow Points

45	1-5	Location (point)	From Map
	6-10	Location of UT plant	Map
	15	0 - intake 1 - outflow	

Sampling Stations

46	1-5	Location	From Map
	6	P = business point source A = ambient M = municipal point source E = all three kinds	

Water Prices

47	1-2	Jurisdiction	Standard price structures
	4-5	Activity type	
	6	--	
	7-10	Price/Ma.	

Typical Rents and Salaries

48	1-5	PL rent	PM taken as median rent from Statistical Abstract - city type income and U.S. trends used to give PL, PH payrolls and employment by business, gov't used to give salaries
	6-10	PM rent	
	11-15	PH rent	
	16-20	PL salary	
	21-25	PM salary	
	26-30	PH salary	

Solid Waste Co - Developed and Undeveloped Land - 51

1-5	Location	Map
8-10	% land owned by SWC	
12-14	Landfill %	
15	Type	
16-20	Tons solid waste to fill site	
23-25	Level of incinerator	
28-30	Level of incinerator air treatment	
33	Type A air treatment	
34	Type B air treatment	
35	Type C air treatment	

Power Co - 52

1-5	Location	From Map
8-10	% land owned by PC	
12	Type	
13-15	Level of power plant	Levels of industry and Master Sheets give level of power plant
18-20	Level of cooling tower	
23-25	Level of air treatment	
28	Type A air treatment	
29	Type B air treatment	
30	Type C air treatment	
33-35	% fuel low grade coal	
38-40	% fuel high grade coal	
43-45	% fuel low grade oil	
48-50	% fuel high grade oil	
53-55	% fuel natural gas	

Solid Waste Collection Levels - 53

1	Level of Collection	
6-10	Location of parcel served	

Power Co. Prices - 54

1	Jurisdiction	Standard price structure
2-5	Normal price	
6-10	Heavy user price	
15-20	Max annual Env. (normal price)	

Solid Waste Co. Prices - 55

1	Jurisdiction	Standard price structure
3-4	Activity type	
5-10	Price	

Solid Waste Co. Contracts and Basic Land - 56

2	Jurisdiction of SWC	Standard price structure
6-10	Location of industry	
11-20	Price/year	

MS and SC Fuel Mix - 57

2	Jurisdiction
3-5	% MS fuel high grade coal
6-8	% MS fuel high grade oil
9-11	% MS fuel natural gas
12-14	%SC fuel high grade coal
15-17	% SC fuel high grade oil
18-20	% SC fuel natural gas

Basic Industry Fuel Mix and Air Treatment - 58

1-5	Location
	etc.